

Purdue University
Purdue e-Pubs

International Compressor Engineering Conference

School of Mechanical Engineering

2002

Noise Characteristics Of A Check Valve Installed In R22 And R410A Scroll Compressors

M. K. Kiem

LG Electronics Inc.

Y. K. Kim

Korea Aerospace Research Institute

D. S. Lee

LG Electronics Inc.

S. Choi

LG Electronics Inc.

B. C. Lee

LG Electronics Inc.

Follow this and additional works at: <https://docs.lib.purdue.edu/icec>

Kiem, M. K.; Kim, Y. K.; Lee, D. S.; Choi, S.; and Lee, B. C., " Noise Characteristics Of A Check Valve Installed In R22 And R410A Scroll Compressors " (2002). *International Compressor Engineering Conference*. Paper 1584.
<https://docs.lib.purdue.edu/icec/1584>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at <https://engineering.purdue.edu/Herrick/Events/orderlit.html>

C20-1

NOISE CHARACTERISTICS OF A CHECK VALVE INSTALLED IN R22 AND R410A SCROLL COMPRESSORS

*Myungkyun K. KIEM, **Youngkey K. KIM, *Dong-soo LEE,
*Song CHOI and *Byeong-chul LEE

*Digital Appliance Research Laboratory, LG Electronics Inc.
(dewlet@lge.com, 327-23 Gasan-Dong, Keumchun-Gu, Seoul, 153-023 Korea)

**Satellite Integration and Test Center, Korea Aerospace Research Institute
(Youngkey@kari.re.kr, 45 Eoeun-Dong, Yusong-Gu, Daejeon, 305-333 Korea)

ABSTRACT

R407C and R410A have been widely used as alternative refrigerants for air conditioners. This paper reports the noise characteristics of a scroll compressor with a discharge check valve when R410A is applied. Since a scroll compressor has the characteristics of a fixed volume ratio, the excessive motion of a check valve occurs under over-compression and under-compression conditions. Moreover, the velocity of the motion increases if R410A, which adopts higher discharge pressure, is employed. In this study, we measured the motion of a check valve (a reed valve) by using a gap sensor and also measured the noise level of a compressor under various operating conditions. The relationship between the noise level and each condition has been investigated. Consequently, the study shows that the noise of a scroll compressor can be reduced by optimising the volume ratio.

NOMENCLATURE

k : Adiabatic Index of Compression	C_r : Critical Point
λ : Volume Ratio	V_s : Volume of Suction Pocket
V_d : Volume of Discharge Pocket	P_s : Pressure of Suction Pocket
P_d : Pressure of Discharge Pocket	P_{d_ideal} : Ideal Pressure of Discharge Pocket

1. INTRODUCTION

Reverse rotation of scroll compressors, which can cause serious wear and noise problems, occurs if the supplied power is shut down. The reverse flow of discharged gas in a discharge chamber affects the reverse rotation directly. As a result, a scroll compressor adopts a discharge check valve that is always opened during normal operation, but closed when reverse flow occurs. This paper describes the behavior and the noise characteristics of a reed valve installed as the check valve in scroll compressors.

The behavior of a check valve highly depends on the pressure distribution around it. Although the check valve of a scroll compressor is opened during operation, it moves rapidly if pressure around the valve fluctuates. Scroll compressors are basically designed to be operated in a certain range of operating conditions. However, the abnormal environmental conditions of condensers or evaporators cause the unfavorable operating conditions. If the pressure of condensers goes up higher than the discharge pressure decided by the geometry of scroll wraps, discharge gases could be in 'under-compressed' condition. It means that a valve is abruptly closed and is hard to be opened. On the other hand, if the pressure of condensers goes down, a valve is opened and 'over-compressed' gases are discharged through a discharge port. These conditions cause rapid motion of a check valve, so that the noise level of the compressor increases. In this paper, the behavior of a reed valve under these conditions is measured by using an eddy current sensor, and the relations between the operating conditions and the noise level are clarified experimentally.

2. THEORY

Figure 1 shows the schematic view of compression process in scroll compressors. Two involutes-shaped scroll members fit together forming crescent-shaped multiple gas pockets. One scroll member remains stationary, while the other scroll member orbits around the stationary one. As the orbiting movement continues, the gas is drawn into the suction pockets and compressed toward discharge pockets. The pocket volumes of suction and discharge are determined by the geometry of scroll members and remain fixed.

The fixed volume ratio λ of a scroll compressor is the ratio of the volume of suction pocket V_s to the volume of discharge pocket V_d as follows.

$$\lambda = \frac{V_s}{V_d} \quad (1)$$

If the compression process is assumed as an adiabatic process, the ideal pressure of discharge pocket P_{d_ideal} could be expressed by

$$P_{d_ideal} = P_s \lambda^k \quad (2)$$

where P_s is the pressure of suction pocket and k is the adiabatic index of compression.

Under-compression and over-compression occur when the pressure of discharge pocket P_{d_ideal} differs from the discharge chamber pressure P_d . If the pressure of discharge pocket exceeds the chamber pressure, a check valve opens rapidly and generates pressure pulsation. In the same time, the under compressed gases cause abrupt close of valve and pressure pulsation. Therefore, the magnitude ΔP is expressed by a differential of P_d and P_{d_ideal} as follows,

$$\Delta P = P_d - P_{d_ideal} = P_s \left\{ \left(\frac{P_d}{P_s} \right) - \lambda^k \right\} \quad (3)$$

ΔP also represents the degree of valve motion.

Figure 2 shows the ideal pressure of discharge pocket versus the pressure of suction pocket when the volume ratios vary with 2.4, 2.6, 2.8, and 3.0. The usual operating envelopes of R22 and R410A scroll compressors are also depicted for reference. The upper-left region shown in Figure 2 means under compression region since the chamber pressure is greater than the ideal pressure of discharge pocket. Oppositely, the lower-right region indicates the over compressed region.

Since not only the magnitudes of under- and over-compression but also the operation envelope depend on working refrigerants, the magnitude of pressure difference in equation (3) also depend on the refrigerants. Comparing the magnitudes of pressure difference for R22 and R410A cases, a simple correlation can be obtained since the adiabatic index of R410A and R22 are approximately same. If the volume ratio of scroll compressors λ is same, the magnitude of pressure difference for R22 and R410A cases could be expressed as follows,

$$\frac{\Delta P_{R410A}}{\Delta P_{R22}} \approx \frac{P_{s,R410A}}{P_{s,R22}} \quad (4)$$

Since operating discharge pressure of the refrigerant R410A is 1.6 times as high as that of the refrigerant R22, the magnitude of pressure difference of R410A is expected to be 1.6 times greater than that of R22. This means that R410A may cause more severe problems due to excessive motion of reed valve.

3. MEASUREMENT EQUIPMENT AND MEASUREMENT METHOD

The behavior of a reed valve and its noise characteristics has been measured. The normal cooling capacities of two scroll compressors having 50Hz rotating speed used for the experiment are 9.4kW for R22 and 8.4kW for R410A, respectively. Both of them have a reed valve on their discharge ports. Detailed measurements were done for the R22 compressor at first, and the verification experiments have been made using the R410A compressor. The diameters of discharge port of the compressors are 10.7mm and 8.5mm, respectively and the geometry of the valve is shown in Figure 3.

The Figure 4 shows the sensor positions inside a compressor. In order to measure the pressure difference between upper and lower sides of the valve, piezo-electric type pressure sensors are mounted in the discharge chamber and the discharge port. The opening height of valve is measured by an eddy-current type displacement sensor, which is mounted on the middle of valve retainer. A displacement sensor mounted on the side wall of the fixed scroll member detects the rotational position of orbiting scroll member. If the orbiting scroll member comes close to the fixed scroll member, the output voltage of the sensor goes down, and otherwise, it sustains a constant value. The noise level is measured with a microphone located at a distance of 700mm above the compressor. An accelerometer attached on the surface of the top cap measures the vibration of the scroll compressor.

The Figure 5 shows the operating conditions used for the experiments, which includes a standard condition suggested by ARI. For R22 compressor, 16 operating conditions that cover almost entire operating conditions are used. For R410A compressors, 9 operating conditions are used. The degrees of suction over-heating and condenser sub-cooling are 11.1°C and -8.3°C respectively as suggested by a standard condition of ARI. The pressure of suction pocket P_s and the pressure of discharge pocket P_d at each experiment are listed in table 1 and table 2.

4. RESULTS AND DISCUSSION

4.1 Noise sources

The noise signals of two experimental conditions C4 and C13 are shown in the Figure 6. Two conditions correspond to the maximum and minimum noise level through 16 experimental cases for R22. The crank angle of 0 degree shown in Figure 6 is a reference angle that means the starting of compression process. If we compare C4 with C13, we could know that the level of noise increases as well as impulsive noise, which could be the result of the valve motion, occurs around 200 degree. The following experimental results shows details.

Figure 7(a) shows the measured signals for the C3 condition, which is under-compression case. The pressure difference between upper and lower sides of valve is nearly 0 Pa in most angles, but it decrease from 160degree to 240degree. It means that under-compression occurs during this moment and the valve is abruptly closed at the beginning of the moment. The output voltage of displacement sensor indicates that the valve is closed during this moment. Moreover, the acceleration signal shows that impulsive noise occurs at the beginning of the moment due to the abrupt close of valve. The impact noise signal, which is detected 700mm away from the top cap, shows time delay.

Over-compression case is shown in Figure 7(b). The pressure difference increases from 150degree, and it becomes to fluctuate. The displacement of valve indicates that it rapidly opens when the over-compression starts. In the same time, impulsive vibration, which may be induced by the valve's impacts against the retainer, occurs. Since the shape of retainer is a curved surface, the level of vibration is weaker than that of under-compression.

Figure 7(c) shows the results of an operation condition C4, where the pressure of discharge pocket is nearly the same as the chamber pressure. Since this case has no pressure difference, the unstable behavior of valve almost does not happen. Moreover, the level of noise is reduced.

4.2 Noise-Level versus Operating-Condition

The Figure 8 shows the measured sound pressure level of a R22 scroll compressor at each operating condition. As mentioned before, if under-compression and over-compression happen, the sound pressure level increases. The sound pressure levels according to the change of pressure difference ΔP , which represents the degree of under- and over-compression, are represented on the diagonal lines as shown in Figure 9. The noise level increases linearly with the increase of the magnitude of the pressure difference. The noise level of over-compression ($\Delta P < 0$) is lower than that of under-compression since the curved shape of a retainer relieves the impact of a valve. Therefore, the noise level can be expressed with the interpolated equations as follows,

$$SPL(dB) = \begin{cases} \alpha_1 \Delta P + \beta_1, & \text{if } \Delta P > \Delta P_{cr} \\ \alpha_2 \Delta P + \beta_2, & \text{if } \Delta P \leq \Delta P_{cr} \end{cases} \quad (5)$$

where ΔP_{cr} represents the shift of graph to the right side.

The shift of the graph can be explained by the difference between theoretical and actual discharge port areas of the scroll compressors. Although theoretical discharge process starts at a certain moment, the actual discharge could be delayed due to the smooth increase of port area. Figure 10 shows the variation of discharge port area of a scroll compressor. It shows that approximately 50 degrees delay is expected before the discharge port is about 60% fully opened.

5. CONCLUSIONS

This study measures not only valve behavior but also the pressures difference around a discharge check valve. Experiments were done by using R22 and R410A scroll compressors at various operating conditions. After investigating the behavior of valve and noise level, we could find out the sources of noise and its characteristics. When under-compression occurs, the valve is closed rapidly and makes impacts against valve seat. On the contrary, the valve impacts against a retainer if over-compression happens. The noise level of over-compression is less than that of under-compression since the smooth shape of a retainer relieves the impact of the valve. Moreover, the minimum value of valve noise appeared when small under-compression exists. It means the graph of noise level versus pressure difference is shifted to right side. The reason of the shift was explained with the effective area of a discharge port. According to this result, the volume ratio of a scroll compressor needs to be designed a little lower than the ideal volume ratio in order to have quiet compressor.

REFERENCES

- K. Tojo, S. Saegusa, S. Machida, T. Hirata, M. sudo, S. Tagawa: "Noise reduction of refrigerator compressors", Proceedings of 1980 International Compressor Engineering Conference at Purdue, pp. 235-242.
- K.Sano and K.Mitsui, "Analysis of hermetic rolling piston type compressor noise and countermeasures", Proceedings of 1984 International Compressor Engineering Conference at Purdue, pp. 242-250.
- J. J. Nieter and D. P. Gagne, "Analytical modeling of discharge flow dynamics in scroll compressors", Proceedings of 1992 International Compressor Engineering Conference at Purdue, pp. 85-96.
- T. Ito, M. Fujitani, K. Takeda, "Investigation of Discharge Flow Pulsation in Scroll Compressor", Proceedings of 1994 International Compressor Engineering Conference at Purdue, pp. 683-688.
- Matsushita Electric Industrial Co. Ltd., US Patent 451148 "Check valve device for scroll compressor," 1995.
- J. W. Bush, "Controlling discharge valve closing impact in scroll machines," Proceedings of 1998 International Compressor Engineering Conference at Purdue, pp. 631-636.
- Y. K. Kim, M. K. Kiem, D. Lee, S. Choi, B. Lee, " Noise of a Discharge Check Valve Installed in a Scroll Compressor with R410A", Transactions of 2001 the JSRAE Vol18, No. 3, pp.341~346

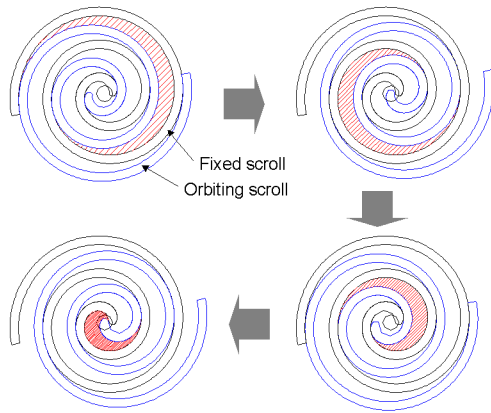


Fig. 1 The compression process of scroll compressor. The volumes of suction and discharge pockets are fixed by the geometry of scroll members.

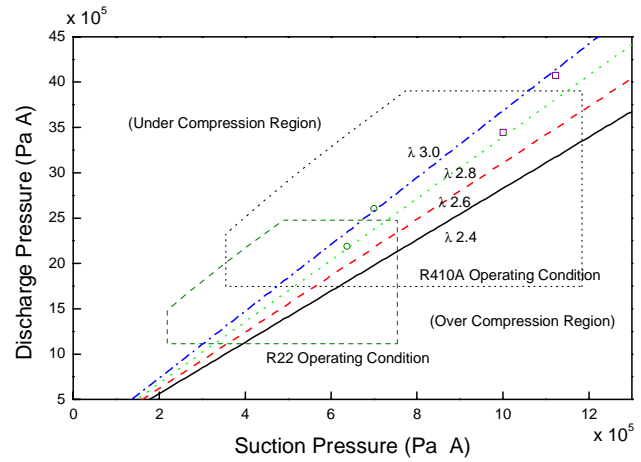


Fig.2 The operating conditions of a scroll compressor and ideal pressure of discharge pockets for various volume ratios

Table 1 Experimental conditions for R22 compressor under $\lambda=2.6$. [Pa x 10⁵]

No	P _s	P _d	P _{d_ideal}	Δn
C1	7	10	21.6	- 11.6
C2	3	15	9.2	5.8
C3	4	15	12.3	2.7
C4	5	15	15.4	- 0.4
C5	6	15	18.5	- 3.5
C6	7	15	21.6	- 6.6
C7	8	15	24.7	- 9.7
C8	4	20	12.3	7.7
C9	5	20	15.4	4.6
C10	6	20	18.5	1.5
C11	7	20	21.6	- 1.6
C12	8	20	24.7	- 4.7
C13	5	25	15.4	9.6
C14	6	25	18.5	6.5
C15	7	25	21.6	3.4
C16	8	25	24.7	0.3

Table 2 Experimental conditions for R410A compressor under $\lambda=2.6$. [Pa x 10⁵]

No	P _s	P _d	P _{d_ideal}	Δn
D1	6.01	36.03	19.5	16.5
D2	6.55	36.03	21.3	14.7
D3	7.21	36.03	23.4	12.6
D4	8.01	36.03	26.0	10.0
D5	9.01	36.03	29.3	6.7
D6	10.15	34.48	33.0	1.5
D7	11.72	41.03	38.1	2.9
D8	10.29	36.03	33.5	2.6
D9	12.01	36.03	39.0	- 3.0

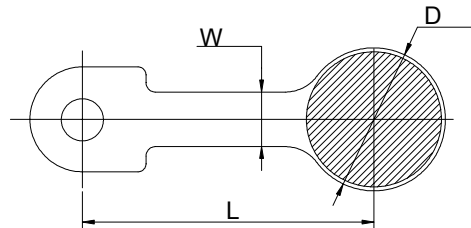


Fig. 3 The geometry of a reed valve used for the experiments.

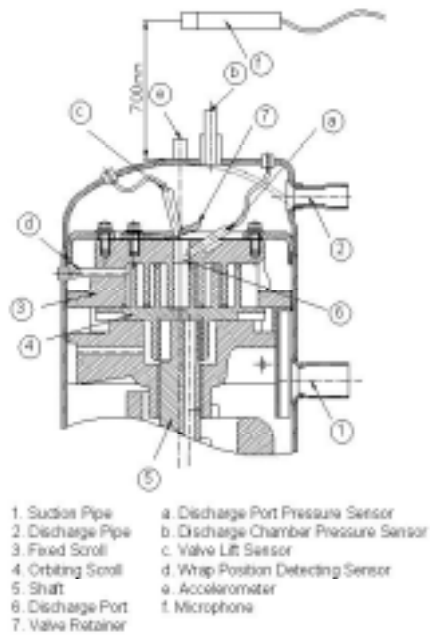


Fig. 4 Sensors installed in a scroll compressor.

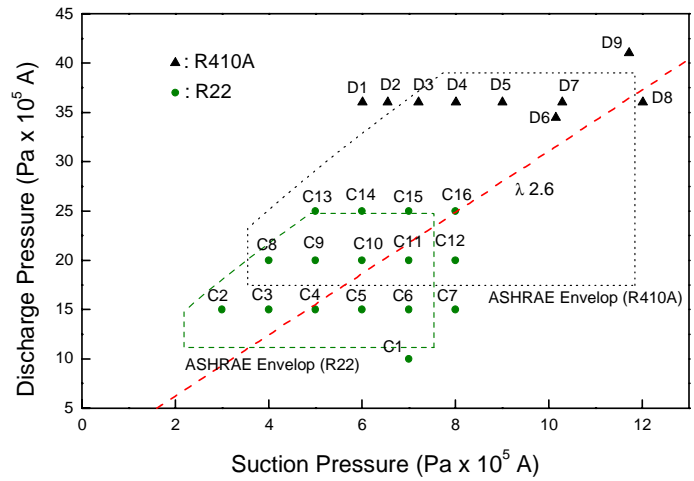
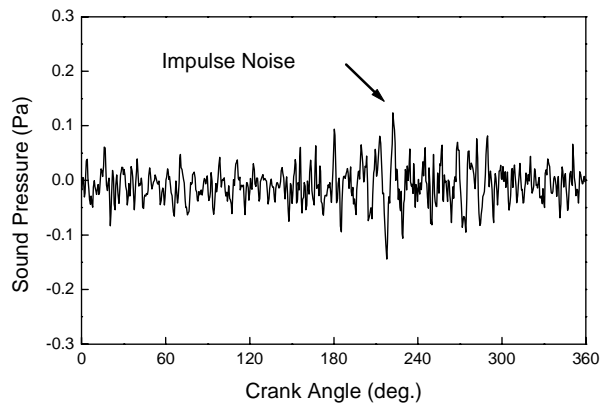
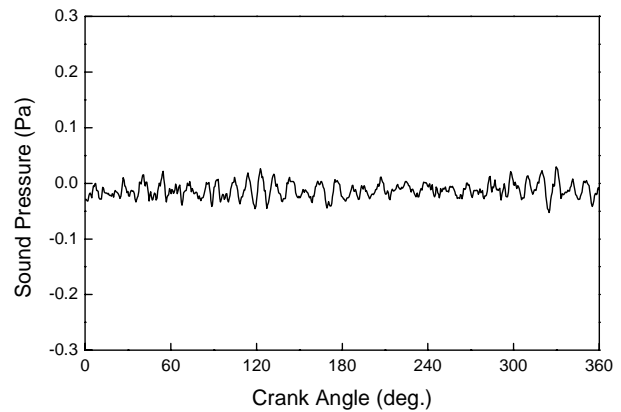


Fig. 5 Experimental conditions. C1 to C16 represent experimental conditions for a R22 compressor, and D1 to D9 shows conditions for a R410A compressor.

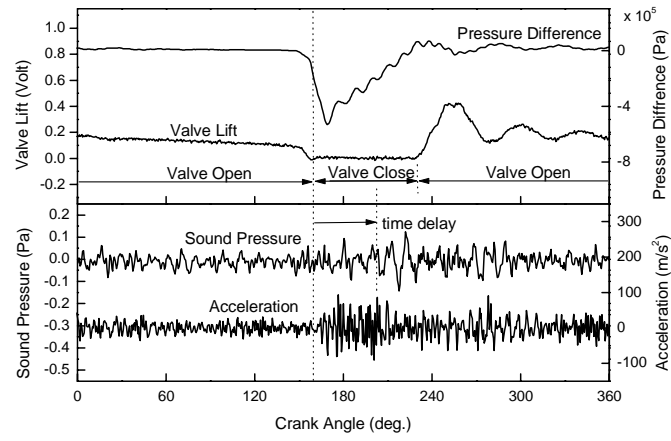


(a) C4 condition

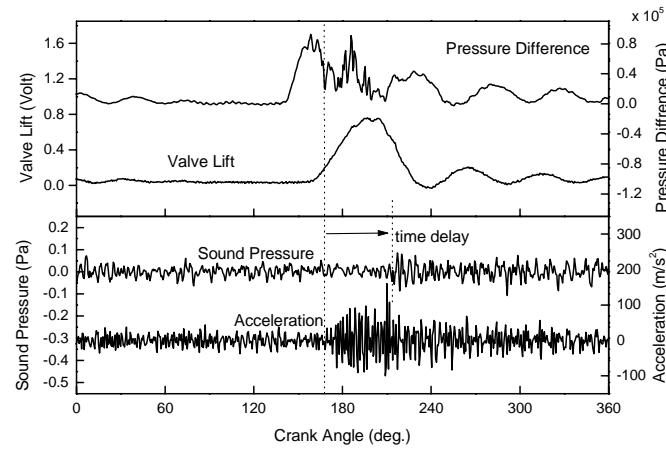


(b) C13 condition

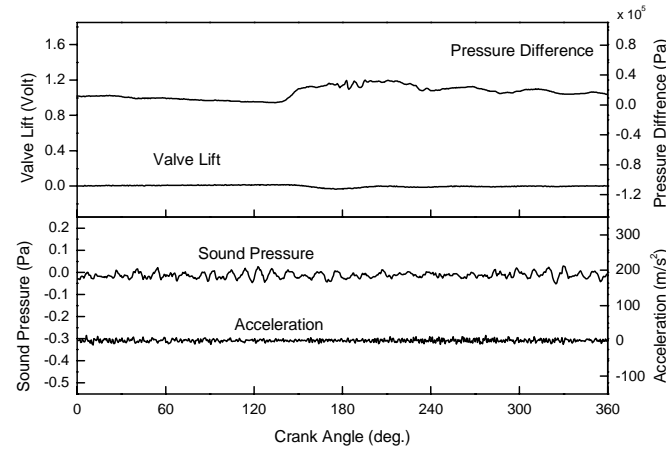
Fig. 6 The noise signals measured at (a) C4 and (b) C13 conditions. C13 reveals maximum noise level while C4 has minimum noise level.



(a) C3 condition



(b) C7 condition



(c) C4 condition

Fig. 7 The valve lift, pressure difference, noise and acceleration measured at different conditions. (a) C13 (b) C7 (c) C4. The dotted lines represent the instance when impact occurs.

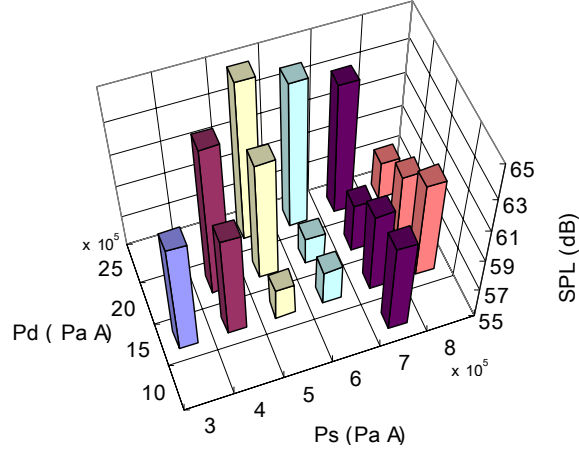
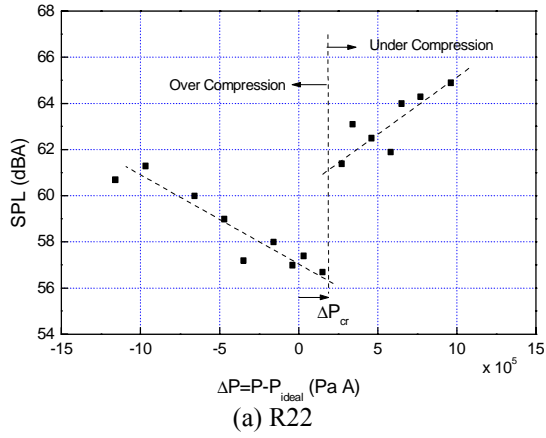
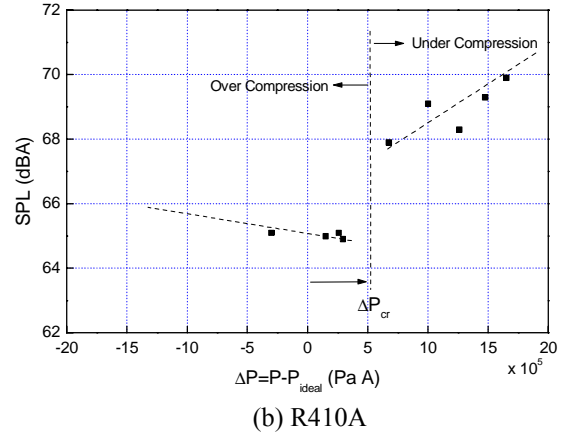


Fig. 8 The sound pressure level measured at 16 different conditions (C1 to C16 in Fig. 5)



(a) R22



(b) R410A

Fig. 9 The sound pressure level for various pressure difference (a) R22 (b) R410A

Fig. 10 Effective discharge port area

